



U.S. Department
of Transportation
Federal Railroad
Administration



TANK CAR FILLING LIMITS



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TANK CAR FILLING LIMITS

- Regulations
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TANK CAR FILLING LIMITS REGULATIONS

§173.24b Additional general requirements for bulk packagings.

- (a) Outage and filling limits. (1) Except as otherwise provided in this subchapter, liquids and liquefied gases must be so loaded that the outage is at least five percent for materials poisonous by inhalation, or at least one percent for all other materials, of the total capacity of a cargo tank, portable tank, tank car (including dome capacity), multi-unit tank car tank, or any compartment thereof, at the following reference temperatures—

Note: See 49 CFR 173.314(c) note 2 regarding allowance of two percent outage (for Anhydrous Ammonia and Ammonia Solutions > 50%)



TANK CAR FILLING LIMITS REGULATIONS

- (i) 46 °C (115 °F) for a noninsulated tank;
- (ii) 43 °C (110 °F) for a tank car having a thermal protection system ...
- (iii) 41 °C (105 °F) for an insulated tank.

Note: See 49 CFR 173.314(c) notes 10 regarding “winter” reference temperatures (for Anhydrous Ammonia and LPG)



TANK CAR FILLING LIMITS REGULATIONS

§173.26 Quantity limitations.

- When quantity limitations do not appear in the packaging requirements of this subchapter, the permitted gross weight or capacity authorized for a packaging is as shown in the packaging specification or standard in part 178 or 179, as applicable, of this subchapter.



TANK CAR FILLING LIMITS

DEFINITIONS

- **Overload** – A condition that occurs when the load is greater than the system was designed to handle. A car can be overloaded by WEIGHT or overloaded by VOLUME or both
- **Specific Gravity** – mass of liquids at a given temperature compared to the mass of an equal volume of water at the same temperature where water = 1
- **Coefficient of Expansion** – the ratio of change in volume per degree in temperature



TANK CAR FILLING LIMITS

DEFINITIONS

Shell Full Capacity

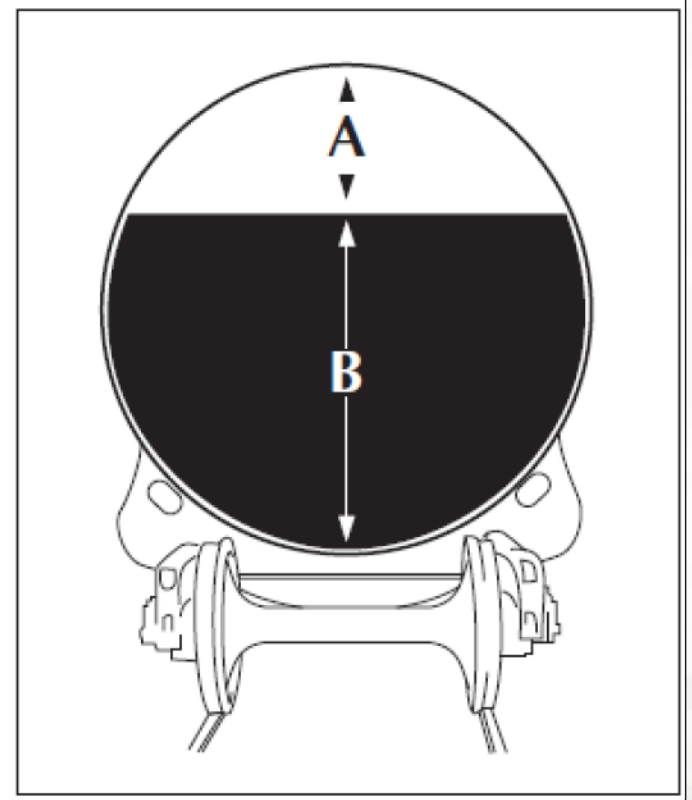
The amount of product in a tank car when the tank shell is completely filled.

Shell Innage

The depth of the product in the tank car measured from the bottom of the tank up to the liquid level of the product, dimension B.

Shell Outage

The unfilled portion of the tank car measured from the inside top of the tank shell down to the level of the product, dimension A.




Source: ARL Tank Car Gauging Instructions



TANK CAR FILLING LIMITS FORMULAS

- Capacity Gallons x Max Innage = Max Gallons*
- Max Gallons x (Specific Gravity @ Reference Temp x Weight of Water) = Max Product Weight*



Note: Weight of Water = 8.32828
lbs/gallon (see 49 CFR 173.314[c] – note 1)

*w/o overloading by volume at reference temperature



TANK CAR FILLING LIMITS

FORMULAS

- $\text{Max Product Weight}^* / \text{Specific Gravity @ Loading Temperature} \times \text{Weight of Water} = \text{Max Gallons at Loading Temp w/o Overloading by Volume}$
 - NOTE: Use this formula if Max Product Weight is less than or equal to Load Limit

- $\text{Load Limit} / \text{Specific Gravity @ Loading Temp} \times \text{Weight of Water} = \text{Max Gallons w/o Overloading by Weight}$
 - NOTE: Use this formula Max Product Weight is greater than car's Load Limit

- $\text{Gallons Loaded} / \text{Gallon Capacity} = \text{Innage}$



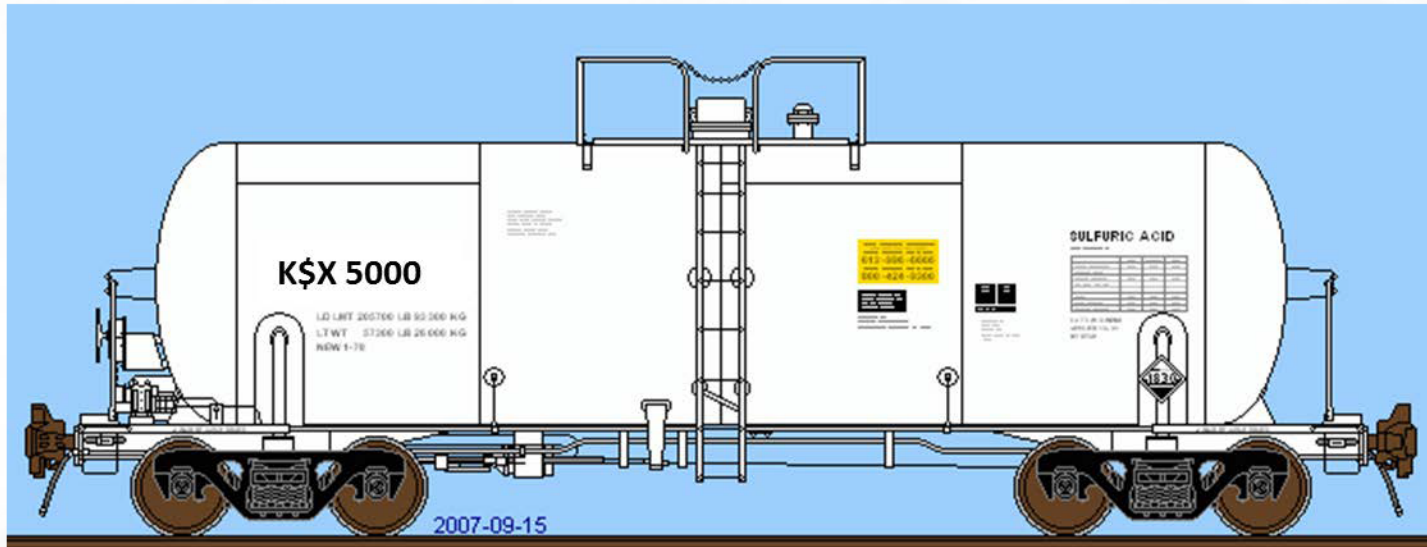
TANK CAR FILLING LIMITS FORMULAS

- Difference b/t two given temperatures x Coefficient of Expansion = Difference in Specific Gravity
- Original Specific Gravity + (or -)* Difference in Specific Gravity = New Specific Gravity
 - * Specific gravity increases as temperature decreases (and visa versa)
- Gross Weight – Tare Weight / Specific Gravity x Weight of Water = Gallons
- Difference in two given SG / Difference in corresponding temperatures = Coefficient of Expansion



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TANK CAR FILLING LIMITS FROM A SHIPPER PERSPECTIVE



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TANK CAR FILLING LIMITS FROM A SHIPPER PERSPECTIVE

- ABC Chemicals loaded and offered Sulfuric Acid tank car K\$X 5000 into transportation. The product temperature at loading was 50F.
- How did ABC Chemicals determine the proper filling limit for K\$X 5000?



TANK CAR FILLING LIMITS FROM A SHIPPER PERSPECTIVE

K\$X 5000 Tank Car Characteristics

- DOT 111A100W2
- Non-Insulated
- 263,000 LBS Gross Rail Load
- 204,900 LBS Load Limit
- 58,100 LBS Tare Weight
- 13,609 Gallon Capacity



TANK CAR FILLING LIMITS FROM A SHIPPER PERSPECTIVE

Sulfuric Acid Characteristics









- 96% concentration
- Specific Gravity of 1.80525 at 115F Reference Temperature
- Specific Gravity of 1.8457 at 50F Loading Temperature




TANK CAR FILLING LIMITS FROM A SHIPPER PERSPECTIVE

K\$X 5000 tank car UMLER

➤ Weight and capacity

Gross Rail Load/Weight	A266	 	263000	263000 lb	←
Tare Weight	A259		58100	58100 lb	←
Load Limit	LDLT	 	204900	204900 lb	←
Weighing Status	A289		A	A - Actual	
Weighing Date	A288		20141219	12/19/2014	
Gallonge Capacity	A297		13609	13609 usgl	←
Star Code	A247				
Qual for Inc GRL	B344				

➤ Insulated vs. Non-insulated

Jacket Material Category	B204		U	U - UNEQUIPPED	←
Jacket Thickness	B541				
Insulation Type	A142				
Insulation Thickness	B259				



TANK CAR FILLING LIMITS FROM A SHIPPER PERSPECTIVE

K\$X 5000 Calculations

What is the maximum innage in gallons without overloading the car by volume at the reference temperature?

➤ Capacity Gallons x Max Innage = Max Gallons*

➤ $13,609 \times .99 = \mathbf{13,473 \text{ gallons}^*}$

*w/o overloading by volume at reference temperature



TANK CAR FILLING LIMITS FROM A SHIPPER PERSPECTIVE

K\$X 5000 Calculations

What is the maximum product weight without overloading the car by volume at the reference temperature?

- Max Gallons x (**Specific Gravity @ Reference Temp** x Weight of Water) = Max Product Weight*
- 13,473 gallons* x (**1.80525** x 8.32828) = **202,562 pounds***

*w/o overloading by volume at reference temperature

Note: This is below the car's load limit of 204,900 pounds



TANK CAR FILLING LIMITS FROM A SHIPPER PERSPECTIVE

K\$X 5000 Calculations

How many gallons can be loaded at 50F without overloading the car by volume at the reference temperature of 115F?

- Max Product Weight* / Specific Gravity @ Loading Temp x Weight of Water = Max Gallons (at Loading Temp)*

- $202,662^* / 1.8457 \times 8.32828 = 13,184 \text{ gallons}^*$

*w/o overloading by volume at reference temperature



TANK CAR FILLING LIMITS FROM A SHIPPER PERSPECTIVE

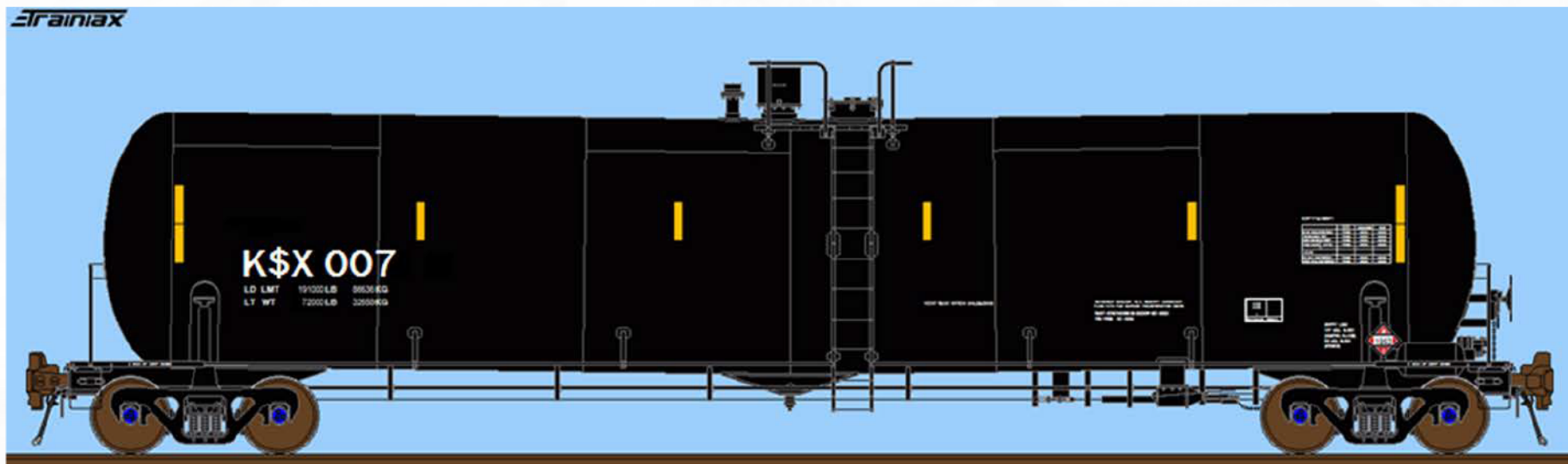
K\$X 5000 Calculations

- ABC Chemicals loaded a maximum of 13,184 gallons (3.1 % outage) at the loading temperature 50F to ensure they had 1% outage at the reference temperature of 115F.
- Gallons Loaded / Gallon Capacity = Innage
- $13,184 / 13,609 = 0.969$ or 96.9% innage or 3.1 % OUTAGE



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TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE



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... based on a true story



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

- XYZ Paper Company loaded tank car K\$X 007 with UN 1993, Flammable Liquid NOS (Spirits of Turpentine), 3, PG III and offered it into transportation.
- FRA observed K\$X 007 experiencing a non-accident release from its protective housing area during transportation. Emergency responders determined the car's NAR emanated from its liquid education valve.



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TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE





TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Tank Car Characteristics

- DOT 111A100W1*
- Insulated (*confirmed to meet insulation standard of 49 CFR 179.200-4 per certificate of construction despite not being a specification requirement for a “W1” tank car)
- 263,000 LBS Gross Rail Load
- 191,000 LBS Load Limit
- 72,000 LBS Tare Weight
- 23,470 Gallon Capacity

179.200-4 requires thermal conductance at 60 °F is not more than 0.225 Btu per hour, per square foot, per degree F temperature differential

Conductivity / Inches = Conductance

CONFIRM WITH OWNER/BUILDER THAT CAR MEETS AND IS MAINTAINED TO INSULATION STANDARD PER 49 CFR 179.200-4 BEFORE USING 105F REFERENCE TEMP



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$ 007 Shipper Provided Loading Information









- 245,600 Gross Weight (shipper scale)
- Loading Temperature of 78F
- Specific Gravity of 0.845 at 105F Reference Temperature
- Coefficient of Expansion = 0.00056
- Outage Table



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Umler

Weight and capacity

Gross Rail Load/Weight	A266	 	263000	263000 lb
Tare Weight	A259		72000	72000 lb
Load Limit	LDLT	 	191000	191000 lb
Weighing Status	A289		A	A - Actual
Weighing Date	A288		19960410	04/10/1996
Gallonge Capacity	A297		23470	23470 usgl
Star Code	A247			
Qual for Inc GRL	B344			

Insulated vs. Non-insulated

Insulation Type	A142		FG	FG - Standard Fiberglass
Insulation Thickness	B259		4.0	4.0 99.9 in

CONFIRM WITH OWNER/BUILDER THAT CAR MEETS AND IS MAINTAINED TO INSULATION STANDARD PER 49 CFR 179.200-4 BEFORE USING 105F REFERENCE TEMP



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Initial Calculations

What is the maximum innage in gallons without overloading the car by volume at the reference temperature?

➤ Capacity Gallons x Max Innage = Max Gallons*

➤ $23,470 \times .99 = \mathbf{23,235 \text{ gallons}^*}$

*w/o overloading by volume at reference temperature



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$ 007 Initial Calculations

What is the maximum product weight without overloading the car by volume at the reference temperature?

- $\text{Max Gallons}^* \times (\text{Specific Gravity at Reference Temp} \times \text{Weight of Water}) = \text{Max Product Weight}^*$
- $23,235 \text{ gallons} \times (0.845 \times 8.32828) = 163,507 \text{ pounds}^*$

*w/o overloading by volume at reference temperature

Note: This is below the car's load limit of 191,000 pounds



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Initial Calculations

What is the specific gravity at the loading temperature of 78F?

- The shipper provided us with the coefficient of expansion (0.00056) and the specific gravity at the reference temperature of 105F (0.845).
- Difference b/t two given temperatures x Coefficient of Expansion = Difference in Specific Gravity
- $(105F - 78F) \times 0.00056 = \mathbf{0.01512}$



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Initial Calculations

- Original Specific Gravity + (or -)* Difference in Specific Gravity = New Specific Gravity
 - * Specific gravity increases as temperature decreases (and visa versa)

- Specific Gravity at 78F = $0.845 + 0.01512 = \mathbf{0.86012}$



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$ 007 Initial Calculations

How many gallons can be loaded at 78F without overloading the car by volume at reference temperature?

- Max Product Weight* / Specific Gravity at Loading Temp x
Weight of Water = Max Gallons*
- $163,507 / 0.860 \times 8.32828 = 22,827 \text{ gallons}^*$

*w/o overloading by volume at reference temperature



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Initial Calculations

Using XYZ Paper Company scale weight (245,600 pounds) and specific gravity of 0.86012 at loading temperature of 78F ... how many gallons were loaded?

- Gross Weight – Tare Weight / Specific Gravity @ Loading Temp x Weight of Water = Gallons
- $245,600 - 72,000 / 0.86012 \times 8.32828 = 173,600 / 7.1633 = 24,235 \text{ gallons}$

Note: This is 735 gallons in excess of the car's 23,470 gallon capacity



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Initial Calculations

How many gallons does this translate to at the reference temperature of 105F?

➤ Gross Weight – Tare Weight / **Specific Gravity @ Reference Temp** x Weight of Water = Gallons

➤ $245,600 - 72,000 / 0.845 \times 8.32828 = 173,600 / 7.0373 =$
24,669 gallons

Note: This is 1,199 gallons in excess of the car's 23,470 gallon capacity



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Initial Calculations

What was the car's outage at loading?

- Gallons loaded / Gallon Capacity = Innage
- $24,235 / 23,470 = 1.0327 = 103.26\%$ Innage or
NEGATIVE 3.26% OUTAGE at loading temperature of 78F



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Initial Calculations

Did XYZ Paper Company actually overload 765 gallons beyond the car's gallon capacity at 78F during loading?

- NO
- Either ...
 - XYZ's scale is inaccurate or ...
 - XYZ's specific gravity is inaccurate
- Revised calculations are required.



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Revised Calculations

Based on FRA's initial calculations, XYZ Paper Company conducted additional product analysis and provided the following information:

- Confirmed 245,600 Gross Weight (shipper scale)
- Specific Gravity of 0.89 at 78F Loading Temperature
- Specific Gravity of 0.8758 at 105F Reference Temperature



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Revised Calculations

Remember ... the maximum innage in gallons without overloading the car by volume at the reference temperature is ...

➤ Capacity Gallons x Max Innage = Max Gallons*

➤ $23,470 \times .99 = \mathbf{23,235 \text{ gallons}^*}$

*w/o overloading by volume at reference temperature



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$ 007 Revised Calculations

What is the maximum product weight without overloading the car by volume at the reference temperature?

➤ Max Gallons* x **Specific Gravity @ Reference Temp** x Weight of Water) = **Max Product Weight***

➤ 23,235 x **0.8758** x 8.32828 = **169,474 pounds***

*w/o overloading by volume at reference temperature

Note: This is below the car's gross rail load of 191,000 pounds



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$ 007 Revised Calculations

How many gallons can be loaded at 78F without overloading the car by volume at reference temperature of 105F?

➤ $\text{Max Product Weight}^* / \underline{\text{Specific Gravity @ Loading Temp}} \times \text{Weight of Water} = \text{Max Gallons}^*$

➤ $169,474 / 0.89 \times 8.32828 = \mathbf{22,864 \text{ gallons}^*}$ (at 78F loading temperature)

*w/o overloading by volume at reference temperature



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Revised Calculations

Using XYZ Paper Company scale weight (245,600 pounds) and the revised specific gravity of 0.89 at the loading temperature of 78F ... how many gallons were loaded?

➤ Gross Weight – Tare Weight / Specific Gravity @ Loading Temp x Weight of Water = Gallons

➤ $245,600 - 72,000 / 0.89 \times 8.32828 = 173,600 / 7.4122 =$
23,420 gallons ←

Note: This is only 50 gallons less than the car's 23,470 gallon capacity



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Revised Calculations

How many gallons does this translate to at the reference temperature of 105F?

➤ Gross Weight – Tare Weight / **Specific Gravity @ Reference Temp** x Weight of Water = Gallons

➤ $245,600 - 72,000 / 0.8758 \times 8.32828 = 173,600 / 7.2939 =$
23,801 gallons

Note: This is 331 gallons in excess of the car's 23,470 gallon capacity



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Revised Calculations

What was the car's outage?

- Gallons Loaded / Capacity Gallons = Innage
- At Loading Temperature of 78F
- $23,420 / 23,470 = .9978$ or 99.78% Innage or **0.22 % OUTAGE**
- At Reference Temperature of 105F
- $23,801 / 23,470 = 1.0141$ or 101.41% Innage or **NEGATIVE 1.41% OUTAGE**



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Subsequent Response and Corrective Offloading

How many *approximate* pounds leaked during transportation?

- Product temperature of 92F during subsequent response and corrective offloading
- SG at 92F = 0.88265 (using coefficient of expansion)
- 0.75 inches outage



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Outage Table

Compartment: Shell Capacity: N/A Tare: N/A Max. Weight on Rail: N/A
Operating Stencil: N/A Length Over Couplers: N/A Extreme Width: N/A Extreme Height: N/A

Inches	US Gallons	Inches	US Gallons	Inches	US Gallons	Inches	US Gallons
0.25	20	21.0	3549	81.0	19193	108.25	23461
0.5	42	22.0	3775	82.0	19424	108.5	23464
0.75	64	23.0	4005	83.0	19651	108.75	23467
1.0	88	24.0	4238	84.0	19875	109.0	23470
1.25	112	25.0	4475	85.0	20096	109.25	23472
1.5	137	26.0	4714	86.0	20312	109.5	23473
1.75	162	27.0	4956	87.0	20524	109.75	23474
2.0	189	28.0	5201	88.0	20732	110.0	23474
2.25	216	29.0	5449	89.0	20936	110.25	23474
2.5	244	30.0	5699	90.0	21135	110.5	23474
2.75	273	31.0	5951	91.0	21329		
3.0	302	32.0	6206	91.5	21424		
3.25	332	33.0	6463	92.0	21517		
3.5	362	34.0	6721	92.5	21610		
3.75	393	35.0	6982	93.0	21701		
4.0	425	36.0	7244	93.5	21790		
4.25	457	37.0	7508	94.0	21878		
4.5	490	38.0	7774	94.5	21965		



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Additional Calculations

- 64 gallons of outage (based on outage table)
- 23,470 (Gallon Capacity) – 64 Gallons = **23,406 Gallons**
(innage at 92F)



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Additional Calculations

What was the approximate product weight at the time of the response but prior to the corrective offloading?

- Gallons x **Specific Gravity @ Response Temp** x Weight of Water = Pounds

- 23,406 gallons x 0.88265 x 8.32828 = 172,056 pounds*

*Product weight at time of response and offloading



TANK CAR FILLING LIMITS FROM AN INSPECTOR PERSPECTIVE

K\$X 007 Additional Calculations

How many approximate pounds were lost during transportation?

- Product Weight + Tare Weight = Gross Weight (or Response Weight)
- $172,056 + 72,000 = \underline{\mathbf{244,056 \text{ POUNDS}}}$ at time of response
- Scale Weight – Response Weight = Pounds Lost
- $245,600 - 244,056 = \mathbf{1,544 \text{ POUNDS LOST}}$



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Questions?